Accuracy of guided biopsy of the jawbone in a clinical setting: A retrospective analysis

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Accuracy of guided biopsy of the jawbone in a clinical setting: A retrospective analysis

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ABSTRACT

The aim of this study was to investigate the accuracy of a previously described technique for guided biopsy of osseous pathologies of the jawbone in a clinical setting. The data sets of patients who had undergone guided biopsy procedures were retrospectively examined for accuracy. Digital planning of the biopsies and manufacturing of the tooth-supported drilling template were performed with superimposed cone beam computed tomography and intraoral scans using implant planning software. After a trephine biopsy was taken using the template, the postoperative low-dose cone beam computed tomography was analyzed for accuracy using the planning software with the corresponding (digitally-planned) biopsy cylinder. The mean angular deviation was $4.35 \pm 2.5^{\circ}$. The mean depth deviation was -1.40 ± 1.41 mm. Guided biopsy seems to be an alternative to a conventional approach for minimally invasive and highly accurate jawbone biopsy.

1. Introduction

In medicine and dentistry, the progress of digitalization not only introduces new treatment options, but also a higher degree of safety and predictability (Coravos et al., 2019). The challenge today is to integrate these new technologies into everyday clinical practice and to transfer the use of existing methods to address new problems. In the last decades, guided implantology has developed into a reliable and accurate method (Schneider et al., 2009; Cassetta et al., 2011; Kernen et al., 2016; Bover-Ramos et al., 2018; Lin et al., 2020a). These advantages can benefit other applications such as jawbone biopsies (Valdec et al., 2019).

Irregularities in the jawbone are often accidently found on radiological scans, but in most cases a histopathological examination is required to make a reliable diagnosis. These osseous lesions form a heterogeneous group of disorders, but their appearances are similar (Slootweg, 1996). The pathophysiology ranges from developmental to reactive or even neoplastic mechanisms (Mainville et al., 2017). In most cases, the bone is replaced with a mixture of variable quantities of osteoid, bone, and cementum-like calcifications (Waldron, 1985). In the majority of cases, these lesions are benign, but they can show aggressive local growth and tend to recur (El-Naggar et al., 2017). Therefore, once they are found, an exact diagnosis is important. Lesion classifications are a controversial topic of discussion and are under constant development and adaptation (El-Naggar et al., 2017). The most relevant guideline is the 2017 World Health Organization (WHO) Classification (El-Naggar et al., 2017), but there are also a large number of other published classifications (Waldron, 1985; Slootweg, 1996; Eversole et al., 2008).

The etiologies vary, and the clinical consequences differ greatly (Mainville et al., 2017). Therapies may include radiological recall, aesthetic surgical revision, systemic management with medications, surgical exploration, or even full resection (Ahmad and Gaalaas, 2018). However, despite the key role of a reliable diagnosis in any treatment plan, a radiologically exact diagnosis is sometimes not made, and some lesions are not biopsied after risk assessment. The risk of injuring neighboring structures such as tooth roots and nerves is frequently cited in favor of conservative monitoring instead of biopsy. In addition, general anesthesia is often necessary to obtain a representative biopsy using

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conventional methods, and postoperative complaints are common after these procedures.

Today's 3-dimensional (3D) imaging, such as cone beam computed tomography (CBCT) and dental scans, can be combined with the knowledge of modern guided implantology to integrate safe and minimally invasive guided bone biopsies into the clinical routine. This method enables challenging bone biopsies to be performed under local anesthesia in a predictable manner, reducing both the risks and the invasiveness (Valdec et al., 2019). However, anatomical conditions such as the locations of the lesion, mouth opening, and existing soft tissue may restrict its use. Also, for other maxillofacial procedures, computer-assisted interventions enable the reduction of operating time and better outcomes for the patient (Van den Bempt et al., 2018; Nilsson et al., 2020).

The aim of this retrospective clinical analysis was to examine the accuracy of template-guided biopsies; the results will guide our recommendations regarding the applicability and adaptation of the method for clinical routines and further procedures.

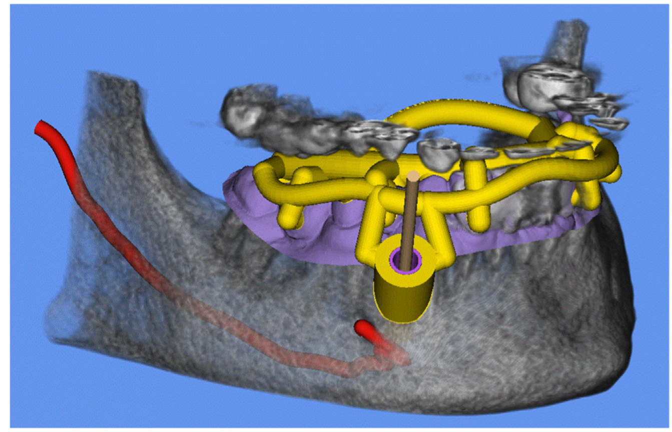

Fig. 1. Superimposed and aligned cone beam computed tomography scan (grey), dental scan (purple), and a digitally designed drilling template (yellow) with a guide for the trephine bur (Case 9).

2. Materials and methods

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Canton of Zurich (Project ID 2020−00833). Due to the retrospective nature of the study, the general consent of the patients was sufficient.

2.1. Study population

This retrospective analysis included patients with bone lesions who underwent guided biopsy at the Clinic for Oral Surgery in the Center of Dental Medicine at the University of Zurich between October 2018 and May 2020. There were no exclusion criteria regarding gender, age, or general diseases.

2.2. Digital planning

For each patient, a preoperative CBCT image (DICOM file) and dental scan (stereolithography file) were superimposed using SMOP implant planning software (Swissmeda AG, Zürich, Switzerland). The cylindrical implant with a diameter of 4−5.75 mm was positioned virtually so that both the pathological lesion and unchanged bone structure were captured by the biopsy. A tooth-supported drilling template, which provides the guide for an appropriate trephine bur and whose outer diameter corresponds to the planned cylindrical implant, was designed and 3D-printed using MED610 (Stratasys Ltd, Eden Prairie, USA) in collaboration with the SMOP service center (Fig. 1).

2.3. Surgery

The operations were all performed under local anesthesia by five experienced surgeons. The drilling template was placed, and the fit was adjusted if necessary (Fig. 2a−e). The template fitting was rated good (no adjustments needed), medium (small adjustments by chairside modifications of the template needed), or poor (unusable). The least invasive surgical approach was chosen, depending on the location (sulcular vestibular and palatinal or mucosal vestibular). After mobilization of the soft tissue and exposure of the bone, the drilling template was positioned. Guided trepan drilling was conducted using a standard-angle handpiece under permanent water cooling with 5.000 RPM to the depth stop (Fig. 2d). After breaking and removing the cylindrical bone specimen, the wound was primarily closed. A postoperative low-dose CBCT scan was taken to verify the biopsy location. Complications during the procedure and the healing process were documented and classified according to the classification of Dindo et al. (2004).

The biopsy specimen was transferred to the pathologist for histopathologic investigation (Fig. 3). Follow-up visits were conducted after 7 and 14 days.

2.4. Accuracy analysis

We used SMOP for our accuracy analysis in accordance with the method used by Kernen et al. (2016). The preoperative CBCT scan was extracted from the initial planning case in STL format, and the surface was smoothed in three steps by using the Laplacian smoothing tool in MeshLab (Cignoni et al., 2008). The postoperative low-dose CBCT scan was imported as a new case using the SMOP planning software. The created preoperative surface was superimposed and aligned with the new case using the SMOP service center. For the accuracy analysis, two experienced surgeons independently placed once a new cylindrical implant with the same dimensions as initially planned in the osseous defect after each biopsy and logged in this position after careful verification. Using congruent alignment via conducted surface matching in the SMOP program, the originally planned cylindrical implant position was loaded into the new case. The software computed the deviation between the planned cylindrical implants and the actual biopsy positions automatically (Fig. 4). We performed a statistical analysis of the angular deviation and the depth deviation in biopsy depth.

2.5. Statistical analysis

Data were computed in Excel (Microsoft Corp., Redmond, USA). A descriptive analysis was performed. The means and standard deviations were calculated for the results from both evaluators. The intraclass correlation coefficients (ICC) with 95% confidence interval (CI) (two-way mixed, average measures, absolute agreement) of the two evaluators for the angle and depth deviations were calculated in SPSS (IBM, Armonk, USA) (Shrout and Fleiss, 1979). An ICC higher than 0.75 indicates a good (Koo and Li, 2016) to very good (Cicchetti, 1994) reliability.

3. Results

In total, 18 guided biopsies were planned, and 14 were included in the analysis (n = 14). Three patients who did not receive postoperative imaging and one patient who experienced intraoperative

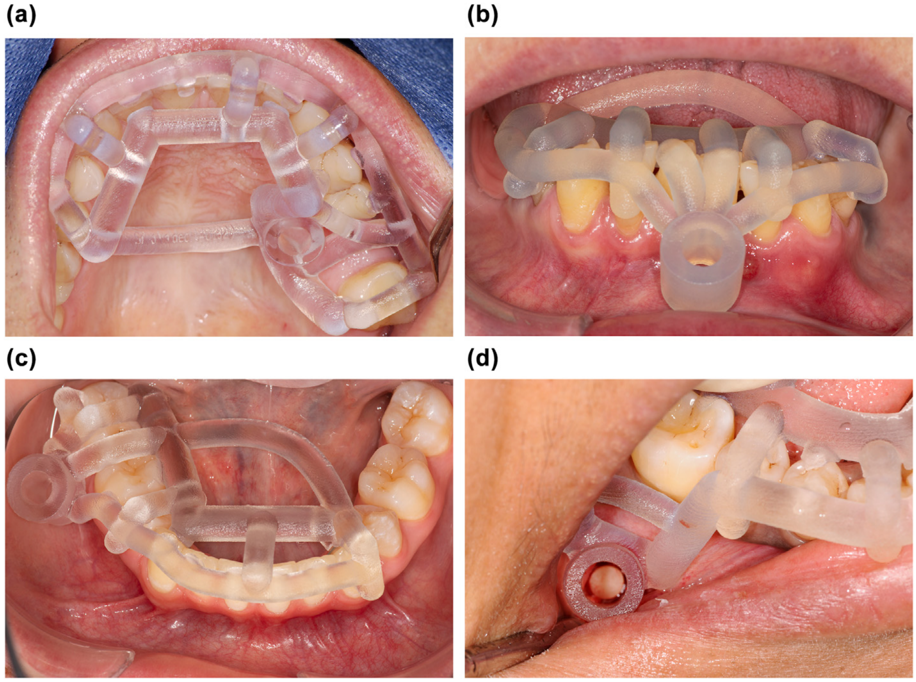

Fig. 2. Drilling templates in-situ with several biopsy locations: a) Case 6: upper jaw palatinal; b) Case 12: lower jaw anterior region; c) Case 11: lower jaw posterior region; d) Case 4: lower jaw posterior region after trephine drilling.

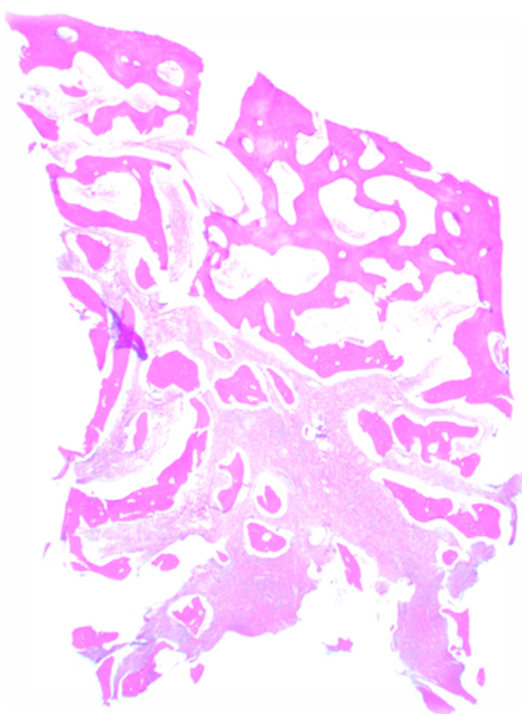

Fig. 3. Histopathological preparation of case 7: Microscopic view of this 2 μm thin section: partially destructed corticospongial bone tissue with chronic inflammation and fibrosis (12,5x). H&E-staining, adapted.

damage to the splint were excluded. The mean angular deviation and mean depth deviation are shown in Table 1. The descriptive statistic of the observer agreement provided the ICC of 0.863 (CI: 0.576–0.956) for the angular deviation and 0.936 (CI: 0.803–0.979) for the depth deviation.

Table 2 shows the cohort and secondary outcomes.

4. Discussion

To the best of our knowledge, this is the first retrospective analysis of guided biopsies in the jawbone. Due to the application of guided dental implantology technologies, comparison of the obtained accuracy with the accuracy in guided implantology is obvious. Our analysis shows promising results for guided biopsies, even though the most current implantology literature indicates higher accuracy values could be achieved for the angle and position of the apex (Kernen et al., 2016; Derksen et al., 2019; Lin et al., 2020b; Varga et al., 2020).

Taking into account the adaptation of a new method, the accuracy of our results is considered good. Comparable in vivo implantology studies report mean values of 2.72°–4.30° for angular deviation and 0.46–1.06 mm for depth deviation (Derksen et al., 2019; Lin et al., 2020b; Varga et al., 2020). The angular deviation of 4.43° ± 2.5° achieved in the present study is within the range achieved with an implant that is drilled, guided and inserted without guidance (4.30° ± 3.3°) (Varga et al., 2020). When compared to an implant, a biopsy provides a wider tolerance to obtain a representative specimen; no exact tooth axis has to be achieved for the prosthetic restoration. In all 14 of the examined cases, a representative specimen was obtained; thus, the objective of the biopsy was achieved.

The procedures were performed by five surgeons, and our results show that the user sensitivity can be considered low. Deviations from the planned position are to be expected due to the necessary sliding fit of the printed sleeve. Although the fit of the template was considered good in all but three cases, minimal movement during drilling cannot be ignored. In addition, studies have shown that the accuracy of surgical guides with distal extension is lower in comparison with accuracy of surgical guides without extension (El Kholy et al., 2019). However, as the location of

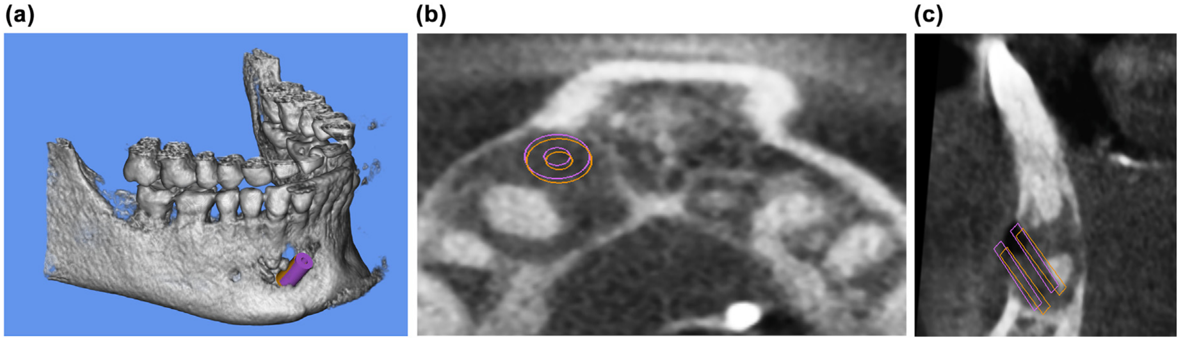

Fig. 4. Accuracy analysis of case 14 (Angular deviation 3.9°, Depth deviation: −0.95 mm): a) superimposition of planned (orange) and realized (purple) biopsy position in 3D reconstruction; b-c) cross-sectional views.

Table 1
Descriptive accuracy analysis: mean angular deviation and mean depth deviation and standard deviation (negative values describe a reduced penetration depth of the bone compared to the planning).

	Angular deviation (degrees)			Depth deviation (mm)		
	Evaluator 1	Evaluator 2	Mean	Evaluator 1	Evaluator 2	Mean
Case 1	2.7	5.2	3.95	−1.98	−2.1	−2.04
Case 2	3.6	2.2	2.90	−1.76	−1.49	−1.63
Case 3	3	1.7	2.35	−3.04	−2.97	−3.01
Case 4	2.4	2.5	2.45	−0.95	−1.27	−1.11
Case 5	2.4	1.5	1.95	0.19	0.33	0.26
Case 6	5.7	3.7	4.70	−2.98	−3.64	−3.31
Case 7	2.9	3.4	3.15	−4.36	−3.93	−4.15
Case 8	10.1	9.5	9.80	−0.19	0.07	−0.06
Case 9	10.4	6.6	8.50	−1.55	−0.32	−0.94
Case 10	1.6	1.8	1.70	−2	−0.6	−0.55
Case 11	5	1.9	3.45	0.49	2.18	1.34
Case 12	3	4.8	3.90	−1.81	−1.88	−1.85
Case 13	9.7	6.8	8.25	−1.65	−1.59	−1.62
Case 14	4.5	3.3	3.90	−0.69	−1.21	−0.95
		Mean (SD)	**4.35** ± **2.5**		**Mean (SD)**	**−1.40** ± **1.41**

Table 2
Case overview with secondary outcomes.

	Age (years)	Gender	Region	Access	Template Fitting	Complications (Grade according to Clavien-Dindo)	Histologic diagnosis
Case 1	34	female	34/35	Sulcular vestibular	Good	-	cemento-osseous dysplasia
Case 2	49	female	34/35	mucosal vestibular	good	-	cemento-osseous dysplasia
Case 3	18	male	45	sulcular vestibular	good	-	odontoma, complex type
Case 4	51	female	46/47	mucosal vestibular	good	intraoperative bleeding (I)	cemento-osseous dysplasia
Case 5	55	female	31	sulcular vestibular	good	-	chronic sclerosing osteomyelitis
Case 6	34	male	26	marginal palatinal	good	-	chronic sclerosing osteomyelitis
Case 7	60	male	46	mucosal vestibular	medium	-	chronic sclerosing osteomyelitis with fibrosis
Case 8	38	female	16	sulcular palatinal	good	-	fibrotic soft tissue
Case 9	50	male	44	mucosal vestibular	good	-	compact bone, cystic tissue
Case 10	55	female	37	mucosal vestibular	medium	delayed wound healing (I)	avital, mature corticospongial bone tissue
Case 11	15	female	46	mucosal vestibular	good	-	solitary bone cyst, compact bone
Case 12	82	female	31	mucosal vestibular	good	-	avital bone with chronic inflammation
Case 13	19	female	43	mucosal vestibular	good	intraoperative bleeding (I)	vital bone
Case 14	34	female	43	mucosal vestibular	medium	-	cemento-osseous dysplasia

a lesion often requires an extended splint design, a higher deviation is to be expected.

In the future, researchers should investigate the dependence of accuracy on the angulation of the biopsy relative to the orthograde tooth axis. Due to the increased lever forces caused by the extended splint design, a higher deviation can be expected with greater angles and distance to the tooth row (Lin et al., 2020a). Depth deviations may be caused by cylinders not fractured at the lowest point before removal and by variations in the hardness of osseous lesions. Less hyperdense lesions were associated with better depth accuracy (Cases 5, 8, and 11). In the future, the samples should be planned deeper depending on the density of the lesion.

Increased temperature is to be expected while drilling due to friction on the large surface of the trephine bur (Lee et al., 2018). This can lead to inaccuracies due to thermoplastic manipulation of the sleeve as well as thermal damage of soft and hard tissue. To prevent this, permanent irrigation and pumping movements are required (Aghvami et al., 2018). The skeletal configuration of the templates allowed for additional irrigation by syringe in difficult conditions. No postoperative complaints due to overheating of the bone were reported in any of the included cases.

During the drilling process, minimal abrasion of the plastic cannot be avoided. It must be expected that minute particles of the plastic will reach the wound area, but these can be removed by extensive rinsing after sample removal. It should be noted, however, that the biocompatible acrylate material used is approved for medical use. One way to avoid this contamination and increase precision would be to use metal sleeves. However, studies have shown that, due to the current accuracy of 3D printing and the necessary tolerances of two metal-guided surfaces, an even lower accuracy would be expected (Tallarico et al., 2019).

Biopsies of intraosseous structures can damage vessels and cause serious bleeding (Romanos et al., 2012). The intraoperative bleeding that occurred in two of our cases shows that this can also be a risk with guided biopsy. The surgeon must be able to control the complications and ensure hemostasis using compression or via hemostyptics, bone wax, or electrical coagulation. However, the procedure can be considered to be low in complications, since all complications occurred are classified as grade I according to Dindo et al. (2004). This classification for general surgery categorizes complications into seven grades. Grade 1 represents any deviation from the normal course without the need for pharmacological treatment or surgical, endoscopic and radiological interventions.

SMOP precision analysis is based on the methodology of Kernen et al. (2016) and was appropriate for our study because the biopsies had already been planned using SMOP software. The software is readily available and has already been used for implant studies (Schnutenhaus et al., 2016, 2018). In this study, only the angle and depth were considered, as they are the most important factors for biopsy positioning. As in all studies utilizing data superimposition, inaccuracies can result from insufficient alignment of the data sets. To reduce this risk, we used the SMOP (the manufacturer of the templates) service center to align the data. The effect of incorrect positioning of the digital biopsy cylinder in the postoperative CBCT scans was reduced by ensuring two experienced users performed the procedure, then calculating the mean value of these two analyses. This effect can be assumed to be moderate, as according to Cicchetti (and Koo and Li, the ICC (0.863 and 0.936) showing a good to very good agreement of the observers (ICC > 0.75) (Cicchetti, 1994; Koo and Li, 2016). However, since digital impressions using a scanbody (as in implant studies) are not possible, the method we employed is a useful option for biopsy analysis.

The knowledge we have gained regarding guided surgery procedures is also valuable in the fields of oral surgery and maxillofacial surgery; it may be used for apicoectomy and tooth autotransplantation, in which bone-drilling precision is important for the therapy's success (Sutter et al., 2019; Mena-Álvarez et al., 2020).

To further improve the accuracy and outcomes of guided surgery, researchers should consider approaches using real-time feedback mechanisms such as auxiliary reflectance sensors. With this technique, the bur position is tracked in real time during the drilling procedure so that corrections can be made if necessary (Sigcho López et al., 2020). However, in contrast to static computer-assisted implant surgery, a noticeable learning curve can be expected in the clinical application of this dynamic navigation (Block et al., 2017; Cassetta et al., 2020). Furthermore, projects in the field of augmented reality (AR) have revealed approaches to improve surgical patient treatment. In addition to providing treatment-relevant information like tumor extension or vulnerable structures in the surgeon's field of view using special visors or glasses, AR makes dynamic navigation during surgery possible (Ayoub and Pulijala, 2019). Although Mediavilla et al. (Mediavilla Guzmán et al., 2019) did not find statistically higher implantation accuracies in vitro, AR should be the focus of future investigations in the areas of implantology and guided biopsy (Pellegrino et al., 2019).

New computer-based technologies promise better safety and accuracy and are also preferred by patients. In particular, the intervention time influences the patient's postoperative quality of life (Sancho-Puchades et al., 2019). For guided biopsy, it is thought that a reduction of the intervention time is feasible; however, further studies are needed.

In conclusion, template-guided biopsy of the jawbone seems to be an alternative to a conventional approach whenever there are no financial restrictions. The possibility of obtaining predictable and safe biopsies with comparatively low invasiveness is a great advantage for both patients and surgeons. Due to the locations of some lesions resulting in difficult access and the necessary extended design of the drill guide, accuracy in guided implantology cannot be achieved. However, biopsies can be performed with sufficient accuracy and minimal invasiveness. Thus, in accordance with a patient's diagnosis, adequate treatment can be planned.

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Ethical approval

Approval by the Ethics Committee of the Canton of Zurich (Project ID 2020–00833).

Patient consent

Patient consent was obtained.

Declaration of Competing Interest

The authors declare no conflict of interest.

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